Using simulators to improve profitability on dairy farms

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Introduction

Dairy farming is a highly dynamic and integrated production system that requires continuous and intense decision-making for improved profitability. Several dairy farm components that include 1) cattle, 2) crops, 3) soils, 4) weather, 5) management, 6) economics, and 7) environment are extremely interrelated [1]. These components and their sub-components dynamically affect and are affected among them. Their individual and aggregated economic impacts are difficult to assess without a systematic and rigorous simulation approach. Therefore, decision support system simulators are critical for successful dairy farming management and decision-making towards economic efficiency and environmental stewardship [2-5].

This paper lists the large number of available simulators at the University of Wisconsin Dairy Management Website aimed to assist dairy farm managers and dairy farm advisors to improve their continuous decision-making and problem solving abilities towards improved economic and environmental sustainability. This paper also demonstrates the practical and real-life application of a selected number of these simulators demonstrating satisfactory system assessment, acceptable future predictability, adequate scenario evaluation, and, consequently, satisfactory decision-making for improved profitability.

These simulators emerged in response of dairy farm managers' needs and were shaped with their input and feedback [6-7]. No single or special methodology was used consistently to develop all of them, but instead a combination and adaptation of methods and empirical techniques with the overarching goal that these always were: 1) highly user-friendly, 2) farm and user specific, 3) grounded on the best scientific information available, 4) remaining relevant throughout time, and 5) providing fast, concrete, and simple answer to complex farmers' questions [2, 8-11]. After all, these simulators become innovative tools converting expert information into useful and farm-specific management decisions taking advantage of latest software and computer technologies.

All the simulators object of this chapter are openly and freely available at http://DairyMGT.info (Figure 1) at the *Tools* section and are categorized within dairy farming management and decision making areas of: 1) nutrition and feeding, 2) reproductive efficiency, 3) heifer management and cow replacement, 4) production and productivity, 5) price risk management and financial assessment, and 6) environmental stewardship (Table 1). Depending on the complexity, the specific purpose, and the

requirements of dairy farm decision makers, some are completely online applications, others are self-contained Spreadsheets, and others are self-extractable and installable programs.

Figure 1. Screenshot of the University of Wisconsin Dairy Management home Website; http:DairyMGT.info.

Table 1. List of dairy farm decision-making simulators openly and freely available (April 2014) at the University of Wisconsin Dairy Management Website (DairyMGT.info/Tools).

Feeding and nutrition
1. ***FeedVal 2012*** – Estimates the fair market value of dairy feed ingredients.
2. ***Grouping Strategies for Feeding Lactating Dairy Cattle***. Evaluates nutritional grouping strategies for feeding lactating dairy cattle.
3. ***Optigen ® Evaluator.*** Calculates the economic value of using Optigen® (a slow-release urea additive) to lactating cows.
4. ***Income Over Feed Supplement Cost.*** Maximizes the income over feed supplement cost for a fixed amount of forage used in the diet and graphs it to a substitution of two selected feed supplements.
5. ***Dairy Extension Feed Cost Evaluator.*** Benchmarks feed costs and income over feed cost for a group of participating herds.
6. ***Corn Feeding Strategies.*** Calculates the income over feed cost, the marginal value of milk to corn, and the optimal level of corn usage for defined milk price, feed costs, and stage of lactation.
7. ***Dairy Ration Feed Additive Break-Even Analysis.*** Estimates the break-even milk production needed to pay for a ration feed additive ingredient.
Heifer management and replacement
8. ***Heifer Pregnancy Rate.*** Calculates the true heifer pregnancy rate of a herd.
9. ***Cost-Benefit of Accelerated Liquid Feeding Program for Dairy Calves.*** Evaluates the use of accelerated heifer feeding programs.
10. ***Economic Value of Sexed Semen Programs for Dairy Heifers.*** Estimates the difference of the net present value of various sexed semen reproductive programs and a conventional semen reproductive program for dairy heifers.
11. ***Heifer Replacement.*** Calculates the number of heifers needed as replacement to maintain constant the herd size.
12. ***Heifer Break-Even.*** Calculates the total cost of raising heifers at 12 months, 24 months, and after 24 months.
Reproductive efficiency
13. ***Wisconsin-Cornell Dairy Repro: A Reproductive Programs Economics Analysis Tool.*** Simulates all cows in a herd and their economics daily, and computes the net return associated to reproductive performance parameters.
14. ***Exploring Timing of Pregnancy Impact on Income Over Feed Cost.*** Combines novel lactation curve definitions with key economic figures to help dairy producers explore the impact of pregnancy timing on milk Income Over Feed Cost.

15. ***Dairy Reproductive Economic Analysis.*** Simulates a dairy herd and their replacements for 9 lactations: from the moment of the first calving to the 9th parturition.

Production and productivity

16. ***Milk Curve Fitter.*** Fits milk curves to user-input observed herd data.
17. ***Decision Support System Program for Dairy Production and Expansion.*** Helps explore "what-if" situations by predicting cash flows. Forecast changes in herd structure for calves, heifers, and cows and their economics.
18. ***Economic Analysis of Switching from 2X to 3X Milking***. Estimates the economic benefit (or loss) of a change in the milking frequency from 2 times a day (2X) to 3 times a day (3X) based on user-defined parameters.
19. ***Lactation Benchmark Curves for Wisconsin.*** Compares Wisconsin benchmark lactation curves with user data.
20. ***Economic Evaluation of using rbST.*** Evaluates the cost/benefit of using recombinant bovine Somatotropin.
21. ***Alfalfa Yield Predictor: Using a Computer Application to Predict Irrigated Alfalfa Yield.*** Predicts the yield of alfalfa according to user-defined fall dormancy, cutting, height, growing degree-days, and rainfall.

Replacement of adult herd

22. ***The Economic Value of a Dairy Cow***. Calculates the projected net return of a cow or the entire herd. It also computes the net return of an average cow in the herd.
23. ***Value of a Springer.*** Calculates the value of a replacement heifer under specific farm conditions.
24. ***Herd Structure Simulation.*** Simulates the dynamics of a dairy herd population on a monthly basis and forecast the future make-up of a herd.
25. ***Retention Pay-Off (RPO) Calculator.*** Calculates the economic value of maintain a cow on the herd.

Health

26. ***Economic Evaluation of CholiPEARL.*** Calculates the return over investment of a given technology that claims to be effective preventing subclinical ketosis.

Price risk management and financial assessment

27. ***Livestock Gross Margin Insurance for Dairy***. Calculates and minimizes the premium price of an insurance contract under farm-specific parameters and selected protection level.
28. ***Working Capital Decision Support System.*** Assists dairy producers in identifying annual cash flow balances for the past 2 years.
29. ***The Wisconsin Dairy Farm Ratio Benchmarking Tool.*** It compares dairy farm's financial status with +500 dairy farms in the State of Wisconsin.

30. ***Milk Component Price Analysis.*** Calculates the value of each milk component and the premium/deduction according to the level of SCC. Performs sensitivity analysis according to different levels of butterfat, protein, other components, and SCC.

Environmental stewardship

31. ***Dairy Nutrient Manager***. Balances nutrients according to user-defined crops planted, soil analyses, effluent irrigated, dry manure applied, and chemical fertilizers supplemented.
32. ***Grazing-N.*** Estimates the N balance for grazing activity of dairy heifers and dry cows.
33. ***Seasonal Manure Excretion.*** Predicts seasonal manure excretion of lactating cows.
34. ***Dynamic Dairy Farm Model.*** Performa dynamic N balances of entire dairy farm systems.

Illustration of Selected Simulators and Practical Decision-Making

Grouping Strategies for Feeding Lactating Dairy Cattle

There is evidence that dairy farmers might be over-feeding a large proportion of lactating cows when they feed the same diet ration to a large group of animals (e.g., same TMR to all lactating cows). Diets are normally formulated to provide enough nutrients to the most productive animals, which in turn gives extra nutrients to the less productive animals. Therefore, splitting lactating cows in smaller groups and offering group-specific feeding rations provide more precise nutrient requirements, increase herd's income over feed cost, and decrease nutrient excretion [12]. The simulator "***Grouping Strategies for Feeding Lactating Dairy Cattle***" calculates dynamically individual cow nutrient requirements and optimizes cow grouping feeding strategies within particular farm constraints.

The value grouping feeding strategies was analyzed by applying the grouping tool to 30 dairy farms in Wisconsin. Test records were collected and adjusted to datasets consisting of cow identification, lactation, days after calving, milk production, and milk butterfat for each cow in each farm. The aim of this analysis was to demonstrate the value of grouping compared to no grouping without knowing studied farms' actual feeding strategies. Therefore, same procedure and assumptions were followed on each analyzed farm: 1) comparison of no grouping versus 3 same-size groups, 2) prices at \$15.89/45.4 kg milk, \$0.14337/0.454 kg CP, and \$0.1174/4.19 mega joules (MJ) net energy, 3) average body weight of 500 kg for first lactation cows and 590 kg for cows in second and later lactations, 4) requirements of CP and net energy at the 83rd percentile level of the group (mean + 1 standard deviation), and 5) a cluster grouping criterion (grouping cows depending on their CP and net energy requirements for maintenance and milk production).

Evaluations clearly and consistently demonstrated that the income over feed cost (IOFC) in all analyzed farms was greater for the 3 feeding groups strategy than the no groping strategy (Table 2).

Table 2. Comparison of income over feed cost (IOFC) of no grouping versus 3 same-size feeding groups for Wisconsin dairy farms assessed by the tool: ***Grouping Strategies for Feeding Lactating Dairy Cattle***.

	Number of lactating cows on analyzed farms (n = 30)	**No grouping IOFC**	**3 same-size feeding groups IOFC**	**Additional IOFC of doing 3 same-size feeding groups**
		----------$/cow per year----------		
Mean	788	2,311	2,707	396
Minimum	<200	697	1,059	161
Maximum	>1,000	2,967	3,285	580

The analysis indicated that farms could realize between $161 and $580/cow per year (mean = $396) of additional IOFC by switching from no grouping to 3 same-size feeding groups using the cluster criterion for grouping. These values represented an increase of between 7 and 52% of farm calculated IOFC. It was concluded then that grouping would have important economic implications in farm profitability and that further analysis should be done at farm-specific level and in a permanent basis by using the ***Grouping Strategies for Feeding Lactating Dairy Cattle*** simulator.

Economic Value of Sexed Semen for Dairy Heifers

Sex-sorted semen that increases the chance of female offspring is a relatively new technology being widely adopted in the dairy industry. Farm-specific sexed semen's economic value and, moreover, when and how to use it, are critical. The tool "***Economic Value of Sexed Semen for Dairy Heifers***" finds interactively the gain (or loss) of different reproductive program management strategies that include sexed semen compared with solely using conventional semen [13].

The ***Economic Value of Sexed Semen for Dairy Heifers*** tool was used for general conditions of Wisconsin dairy farms based on data of a sample of 309 dairy farms and 38 custom heifer growers, a survey performed by county extension agents [14]. At the time of the analysis, using the aggregated data of the 347 operations, the average economic benefit of using sexed semen, as calculated by the tool, was $30 per heifer. Results confirmed that most of these farmers were using optimally this new technology. They were using it for first and second service only, which was the same optimal strategy found by the tool [14]. A main conclusion of this analysis was that the sexed semen technology has an economic benefit, but it would be mostly recommended when the conception rate of the sexed semen is at least 80% of the conventional semen, the value of the heifer calf is high, and when the price of the sexed semen is twice or less than that of the conventional semen. Due that the conception rate of both the conventional and sexed semen and the market prices are important determinant parameters, a main recommendation was that the analysis should be performed on a farm-specific basis and on a permanent basis, for which the decision support tool plays an important role.

Dairy Reproductive Economic Analysis

As important as to find out the value of specific-defined reproductive programs -which can be performed using the ***Wisconsin-Cornell Dairy Repro: A Reproductive Programs Economics Analysis Tool-*** is to explore the value of improving the overall reproductive efficiency. The tool "***Dairy Reproductive Economic Analysis***" is a Markov-chain stochastic dynamic model packed in a simple-to-use online application. This simulator integrates detailed parameters of pregnancy, abortion, and culling risks to perform iterations during 9 lactations until a herd reaches a steady state [15]. Then, the economic value of a

reproductive program is determined by using predicted milk production curves, calve value, replacement costs, and other economic figures. The end result is a net return tied to a reproductive performance.

Published data along with dairy farm records were collected and summarized to create a representative farm to assess the value of improving reproductive efficiency measured as improving the 21-day pregnancy rate using the tool ***Dairy Reproductive Economic Analysis***. Data consisted of detailed information on transition probabilities arrays of replacement and abortion risks; definition of lactation curves, and several economic parameters. Then, the simulator was used multiple times to represent incremental gains in reproductive efficiency.

A marginally decreasing trend of economic gain with respect to 21-day pregnancy rate is seen in Figure 2: the higher the original 21-d pregnancy rate, the lower the gain. Nonetheless the tool shows clearly that even at 30% 21-day pregnancy rate, an extremely good pregnancy rate, there is still an opportunity of additional gains because of improved reproductive efficiency. The tool, furthermore presents the main factors from which the additional value comes (in order): higher milk income over feed cost, lower culling costs, higher calf revenues, and lower reproductive costs. These results are being used in a large extension program (*repro money*, http://fyi.uwex.edu/repromoney/) to promote improved reproductive efficiency in hundreds of dairy farms, but always with the final recommendation that specific farm data and information from current market conditions should be used with the simulator to have a more precise assessments.

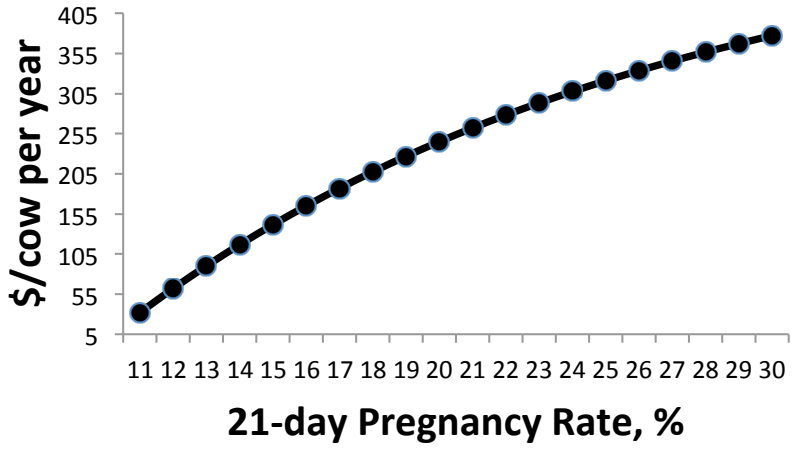

Figure 2. Projected net economic gain of improving 21-day pregnancy rate from a baseline of 10% assessed by the tool ***Dairy Reproductive Economic Analysis***.

Decision Support System for Dairy Production and Expansion

Some dairy farmers are also interested in the possibility of either expand or modernize their farm facilities or increase their herd size. Therefore, they require support on important decisions that will drive the future of the dairy farm operation. The tool "***Decision Support System for Dairy Production and Expansion***" is a Spreadsheet application that allows dairy farmers to outline their current farm conditions regarding herd structure and market conditions, define a possible plan of expansion or modernization including required loans (for facilities and animals), and project the cash flow of the entire farm up to a period of 54 months in the future.

Three hundred dairy farms completed a mailed questionnaire regarding their desires and needs of expansion or modernization [16]. Seventy eight percent of farms (26% of respondents) indicated that were planning to expand or modernize their installations and listed as the most important reason of doing that the expected increase on farm net return. Importantly, they acknowledge largely the uncertainty of the process of expansion as a large hindrance and therefore they asked for decision support tools that would allow them project systematically their options and analyze scenarios. More than 20 of these farmers were then contacted and offered to perform those projections by using the tool ***Decision Support System Program for Dairy Production and Expansion***. The overall outcome was that all farmers agreed that the tool represented reasonably well their farms and therefore they would trust its future projections. Further analyses were used to confirm or reject their pre-conceived evaluations and to assist farmers make more informed decisions throughout the process of expansion or modernization. At least 10 farmers did some adjustments in their expansion or modernization process because of the tool and all of them indicated will continue using the simulator throughout their expansion or modernization operation.

The Economic Value of a Dairy Cow

Dairy farmers need to make critical decisions if to keep or replace cows from the herd. The optimal decision will depend on which alternative would bring a greater net return in the future. The tool "***The Economic Value of a Dairy Cow***" is a complex Markov-chain simulation model, still a user-friendly application that calculates interactively the economic value of a cow (or the value of each single cow in a herd) compared with its replacement [17]. Farmers use this value to make more informed decisions if to keep or replace cows. This tool, in addition, calculates the expected herd demographics and the average herd net return for better and additional dairy farm management and decision-making.

Representative data from Wisconsin farms were collected from official sources, farm records, and market reports to become a baseline scenario [17] from which users could select modifications according to their own conditions. Results of these data contained in the tool ***Economic Value of a Dairy Cow*** indicated that the expected milk production of the cow was the single most important factor for replacement decisions. The impacts of increasing or decreasing up to 20% the average milk production of a cow are portrayed in Table 3. It is

evident that the milk production expectancy of following lactations is a much more important factor for pregnant cows whereas the impact of milk production expectancy of this lactation and future lactations are similarly important factors for non-pregnant cows.

Table 3. Impact of expected milk production on the cow value of a 2-month pregnant, 8-month after calving cow and a non-pregnant, 7-month after calving cow assessed by the tool ***Economic Value of a Dairy Cow***. Bolded values represent the cow with average production in the herd (100%).

Expected Milk Production (% of the average cow)		Cow Value of a 2-month pregnant, 8-month after calving cow, $			Cow Value of a non-pregnant, 7-month after calving cow, $		
Rest of Lactation[1]	Successive Lactations[2]	1st Lactation	2nd Lactation	3rd Lactation	1st Lactation	2nd Lactation	3rd Lactation
120	120	2,458	2,038	2,002	1,973	1,485	1,462
120	100	1,045	877	829	1,109	857	814
120	80	-380	-284	-345	244	230	165
100	120	1,891	1,499	1,477	1,184	796	809
100	**100**	**479**	**338**	**304**	**320**	**168**	**161**
100	80	-934	-823	-870	-545	-460	-487
80	120	1,325	961	952	395	106	157
80	100	-88	-200	-221	-469	-521	-491
80	80	-1,501	-1,361	-1,395	1,344	1,149	-1,139

[1]Cow's expected milk production (% of the average cow) from the current state to the end of the present lactation. [2]Cow's expected milk production (% of the average cow) in all successive lactations.

Although these numbers are good indicators for farm decision-making, the need of using the tool with specific farm conditions and under current market condition cannot be over emphasized.

This tool ***Economic Value of a Dairy Cow*** was also used to value the animal farm assets in a farm. The tool was first set with all parameters concerning to the specific farm and with economic variables representing the market conditions. Followed, the farmer created a list of all cows in the farm including their current state (lactation, month after calving, and pregnancy status) and, importantly, their projected milk production. Then, a cow value was calculated for every single cow in the herd. Finally, the calculated salvage value was added to the cow value. The farmer was then able to use these data for continued monetary support from a financial institution.

Future Developments: Keep Up with Technology and Needs

A number of emerging and evolving technologies are available to dairy farmers today more than ever. These include the use of smart phones, tablets and similar hardware devices; more efficient software resources; and improved data networks. There is no doubt the trend of fast technological improvement in the area of computer, software, and gadget development will continue even at a faster pace. Progressive farmers and an increasing proportion of extension agents and dairy farm consultants are already using these technologies. New technologies bring challenges to keep information systems up-to-date, but at the same time bring great opportunities for improved development of simulators.

One important advantage of smart phones and tablets is their portability along with connectivity. Nowadays farmers enjoy voice and, importantly, data network and therefore the capability to save and retrieve data eventually from anywhere at anytime. For example, a farmer can have complete information of a cow (e.g., age, lactation, pregnancy status, production history, today's production, genetic background, health incidence, etc.) at the fingertips at any time. Farmer can know if the cow currently is in a corral, in the milking parlor, or out in the field grazing. This gives the farmer the opportunity to make critical and time-sensitive decisions right away. This could be one of the major benefits of smart phones and tablets applications. Simulators have to be integrated with these new technologies and need to take advantage of these important advantages.

One drawback, however, of smart phones and tablet applications is their restricted screen size and some hardware and software limitations. Applications need to be especially designed for smart phones and tablets. Normally, the information entered and retrieved would need to be summarized or would require additional layers of navigation. Extra design details could, though, lead to more compact, more intuitive, and overall more efficient simulators.

There is a trade-off of functionality and payback. The industry seems to favor both types: applications for conventional computers and laptops in addition to those applications for smart phones and tablets. The decision-maker selects what type of tool to use for a particular situation. From the developmental standpoint, this is an additional challenge that requires additional work and expertise.

Important considerations regarding upcoming and developmental technologies are the increasing need for integration of simulators with information systems currently used in a farm. Most of the farmers are already using some type of software or informational systems for operational management such as feeding, general record keeping, reproductive synchronization programs, identification, heat devices, or others. The simulators portrayed in this paper and similar have the opportunity of becoming a bridge among these information systems. Simulators can use live information from farm records and provide predictions that go beyond the simple record keeping summaries. Farmer expertise combined with real-time projections using farm record keeping systems is a powerful

combination for efficient and effective decision-making in dairy farm management towards economic and environmental efficiency and improved profitability.

Conclusion

More than 30 computerized simulators have been developed to assist dairy farmers in their continuous decision-making needs. All these tools are openly and freely available at the University of Wisconsin Dairy Management Website, http://DairyMGT.info, under the *Tools* section. Simulators are grouped in major management areas of dairy farming such as feeding and nutrition, reproductive efficiency, heifer management and replacement, production and productivity, price risk management and financial assessment, and environmental stewardship. The ultimate goal has always been to provide solid, but still user-friendly management tools for dairy practical farm decision-making. Simulators have proven to be effective decision-making tools for improved dairy farming operation and profitability.

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